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ABSTRACT

Meteor counts from the observations of the Harvard-Smithsonian Radio Meteor Project at four magnitudes in the range of about +9 to +15 in the visual scale were used to determine the exponent of the mass-distribution law under certain assumptions. Since for these data no range measures were available and since the pattern of the transmitting/receiving antennas is very broad, the same range and radiant distribution were assumed for all counts within the same half-hour during which individual counts at different magnitudes were obtained.

These echo counts, covering in 5 successive days 24 hr with overlapping periods, yielded for the exponent a value of 1. 95 ± 0. 02, close to other determinations. Individual values, however, presented a considerable scatter, probably reflecting changes in radiant and mass distribution over the year.

From the same data, it appeared that the mass exponent changed during the day, yielding generally a higher value for the evening hours.

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INTRODUCTION

The number of meteoroids entering the earth's atmosphere increases as the magnitude increases. If the number N_m of meteoroids having mass m and larger can be expressed as

$$N_m \propto m^{-s+1} \quad ,$$

then, assuming a linear dependence between the mass and the electron line density q produced by a meteoroid, the distribution of meteor trails with line density q and larger will be

$$N_q \propto q^{-s+1} \quad .$$

If the number N_q is known at different limiting values of q, a determination of the exponent s can be attempted. The exponent s has been computed from meteor data at different magnitudes; its value ranges between 2. 5 and 2. 2. Hawkins and Upton (1958) find a value 2. 34 for s over a magnitude interval -1 to +4; Šimek and McIntosh (1968), 2. 35 between +5 and +10; Kaiser (1961), 2.17 between +8 and +11; and Öpik (1958), ~2. 2 between +2 and +5. The recent results of Šimek and McIntosh (1969) do not change the conclusions of their earlier paper.

Meteor counts at four different limiting magnitudes, from approximately +9 to +15, were recorded during normal operations of the Harvard-Smithsonian Radio Meteor Project, and s was derived from these observations. The radar operates at a wavelength of 7. 331 m, with a peak power of about 3 MW and antenna gains near 20 db over an isotopic radiator.

The electron line density is known to be dependent on the meteor's velocity and zenith angle as well as on its mass, and the observed velocity and radiant distribution vary over the day. In consequence, diurnal average values of s are more meaningful here than values at particular times of day. It has not been possible to correct the data for observational height limitations, which must have some effect. The diffusion ceiling and recombination floor on heights (Southworth, this volume) will eliminate some relatively small and large line densities, respectively. Nonetheless, since we unexpectedly observed many large and small line densities compared with intermediate densities, diffusion and recombination appear to be unimportant to an overall determination of s.

ECHO COUNTS

The observed meteor rates are automatically recorded by the radar equipment, which counts the meteor echoes received in given intervals of time, down to four different limiting receiver sensitivities covering the useful dynamic range of the system. The magnitude range is about $+9 < M < +15$ in the radar scale.

Counts are obtained every half-hour, with each receiver level sampled at least once. Counts for the faintest meteors, detected down to the receiver noise, are increased by spurious echoes, even though the equipment was specifically designed to keep these events to a minimum. Spurious counts are probably recorded at the highest level of receiver sensitivity as well, owing to airplane echoes from a nearby airport. Both limitations must be considered in the analysis of the data. During the recording, the transmitted peak power is monitored, as well as the receiver sensitivities at each level.

Observations are usually carried out on 5 consecutive days, each with an average of about 10 hr of continuous recording. The periods of recording are shifted to cover a full 24 hr with overlapping observations.

From these counts, it is possible to derive a diurnal variation of rate that represents the observations of a whole week. The sums of the counts of each half-hour at each level of sensitivity are normalized to this observed diurnal-rate curve to allow for the fact that these data are obtained on different days and over different periods of the day, during which the meteor rates can change considerably.

ANALYSIS AND RESULTS

Rates are discussed here in terms of a convenient parameter

$$L = 10^{10} \sqrt{P_R / P_T} \quad ,$$

where P_T is the transmitter power and P_R is the limiting receiver sensitivity; both varied slightly from time to time. With a mean antenna power gain of 110 and a mean slant range of 135 km, the mean limiting electron line density is

$$q = 4.5 \times 10^9 \ L \quad .$$

Denoting by N_L the hourly number of meteor echoes exceeding a given L, a least-squares fit of $\log_{10} N_L$ versus $\log_{10} L$ has been made on the data covering the period October 1968 to November 1969.

A linear fit was made for each of the 24 weeks of observations and for selected groups of hours from the reconstructed daily rates. Proper weights were introduced in the least-squares solutions to take in account false events and statistical fluctuations in N_L. The variation of the slope s with time is plotted in Figure 1, where the dotted line indicates the results from the mean rate over 24 hr, and the solid and the dashed lines show s from the mean of 4 hr in the morning (5^h to 8^h) and in the evening (17^h to 20^h), respectively. The slope s, derived from a fit combining all the data, is shown in Figure 2, where the mean N_L over 24 hr is plotted versus L. The values s for the different mean rates, together with their errors, are given in Table 1.

The morning observations include a relatively large number of retrograde orbits, and the evening hours, of direct low-eccentricity orbits, while the large counts from the ecliptic streams of moderate eccentricity are included only in the 24-hr averages. Nonetheless, in view of the other diurnal variations, it is difficult to interpret the apparent diurnal changes in s.

A mean daily variation of meteor rates, plotted in Figure 3, was deduced from all the data for the four limiting magnitudes. Similar theoretical curves were obtained by Elford and Hawkins (1964) from the study of the orbits of sporadic meteors and from the geometry of the radar system.

The curves of Figure 4, where the mean rate for each week of observations is plotted versus the time of the year, are in good agreement with the distribution of sporadic meteors over the year as found by Kresáková and and Kresák (1955) from telescopic observations and by Weiss (1957) from radar echoes. This accordance among different surveys seems to indicate that the distribution of sporadic meteors does not change significantly with the years.

CONCLUSIONS

The observed rate of radio meteors depends on many factors, the most important being the equipment parameters, the ionizing process, and the radiant distribution. To calculate the mass exponent s from the echo counts obtained in Havana, it was necessary to make some assumptions and assign certain values to unknown constants. First, since no range measures are available for these counts, the same range distribution was assumed at each limiting magnitude; second, with the antenna pattern very broad and the side lobes conspicuous, the same radiant distribution was assumed for all the counts of each half-hour of recording. The true count of meteor echoes exceeding a certain minimum electron line density is undoubtedly different from the observed count because of the lack of knowledge of range and antenna gain for each returned echo. Once these parameters are assumed, the exponent s can be calculated with some confidence.

The value found for s is 1.95 ± 0.02; it is lower than the determinations cited above but close to the values of Kaiser (1961) and Öpik (1958). When the exponent is determined over a different magnitude range, different values of s are obtained, as can be seen in Table 1.

The variations of s with time as seen in Figure 1 (dotted line) are probably due to changes in the radiant distribution and the mass distribution. Known streams do not contribute substantially to the observed rates, since they are observed only for short periods of time, if at all. However, unknown showers might be responsible for this scatter.

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REFERENCES

Elford, W.G., and Hawkins, G.S., 1964, Meteor echo rates and the flux of sporadic meteors, Harvard Radio Meteor Project Res. Rep. No. 9.

Hawkins, G.S., and Upton, E.K.L., 1958, The influx rate of meteors in the earth's atmosphere, Astrophys. J., 128, 727-735.

Kaiser, T.R., 1961, The determination of the incident flux of radio meteors. II. Sporadic meteors, Mon. Not. Roy. Astr. Soc., 123, 265-271.

Kresáková, M., and Kresák, Ľ., 1955, On the activity of telescopic meteors and some related problems, Contr. Astr. Obs. Skalnaté Pleso, 1, 40-77.

McIntosh, B.A., and Šimek, M., 1969, Mass distribution of meteoroids as determined by radar observations of underdense meteor trails, Canadian J. Phys., 47, 7-22.

Öpik, E., 1958, Statistical results from the Arizona expedition for the study of meteors, Contr. Armagh Obs. No. 26, 1-82.

Šimek, M., and McIntosh, B.A., 1968, Meteor mass distribution from underdense-trail echoes, in Physics and Dynamics of Meteors, edited by Ľ. Kresák and P.M. Millman (D. Reidel Publ. Co., Dordrecht, Holland), pp. 362-372.

Southworth, R. B., this volume, page .

Weiss, A.A., 1957, The distribution of the orbits of sporadic meteors, Aust. J. Phys., 10, 77-102.

Table 1. Exponent s and its error for different mean rates.

Magnitude interval	Mean rate	First-order polynomial	
		s	Standard error
+9 < M < +15	24 hours	1.95	0.02
	morning hours	2.14	0.05
	evening hours	2.26	0.10
+11 < M < +15	24 hours	2.19	0.04
	morning hours	2.23	0.07
	evening hours	2.49	0.14
+9 < M < +13	24 hours	1.82	0.03
	morning hours	1.96	0.05
	evening hours	1.85	0.08

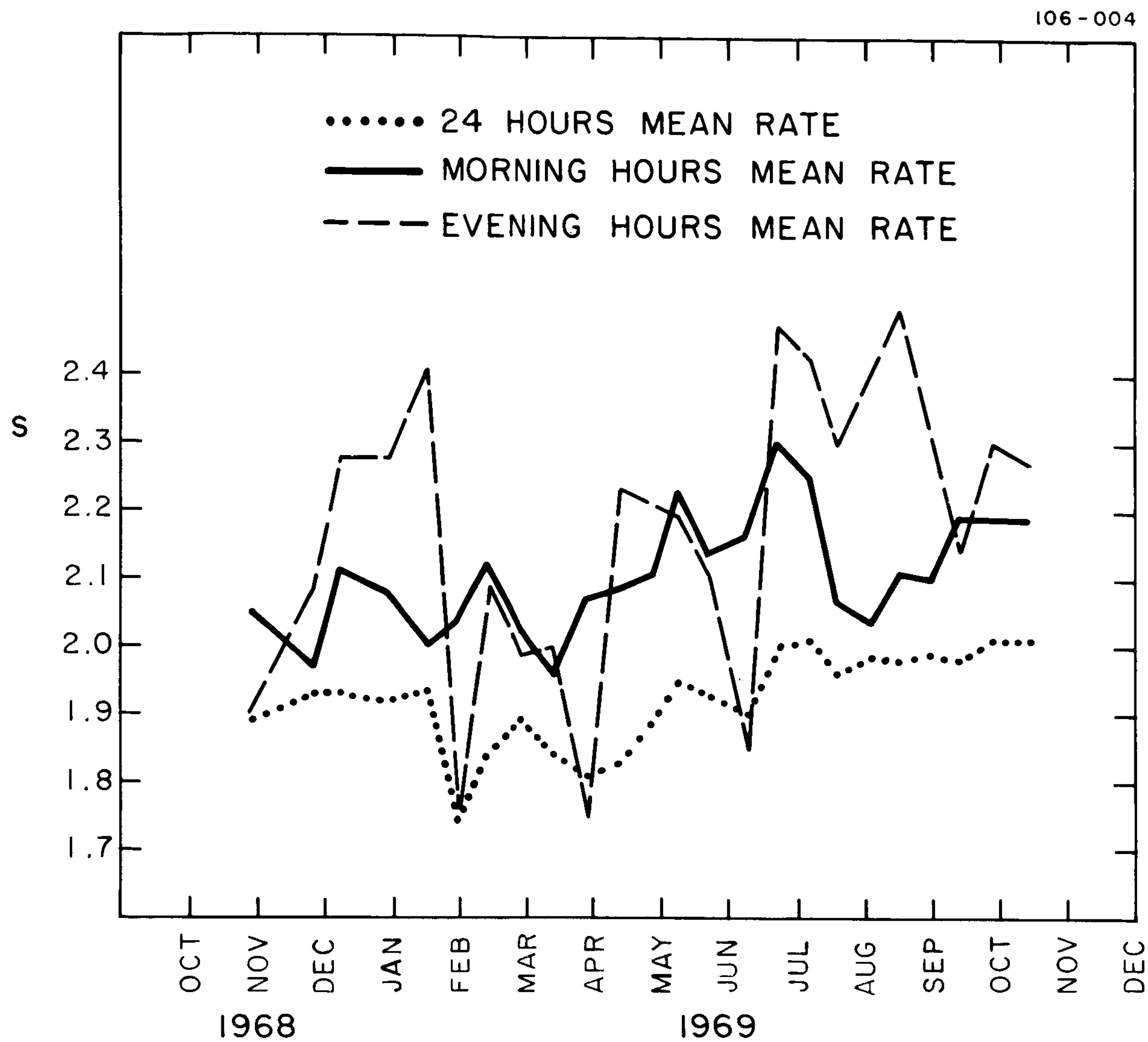

Figure 1. Exponent s as a function of the date.

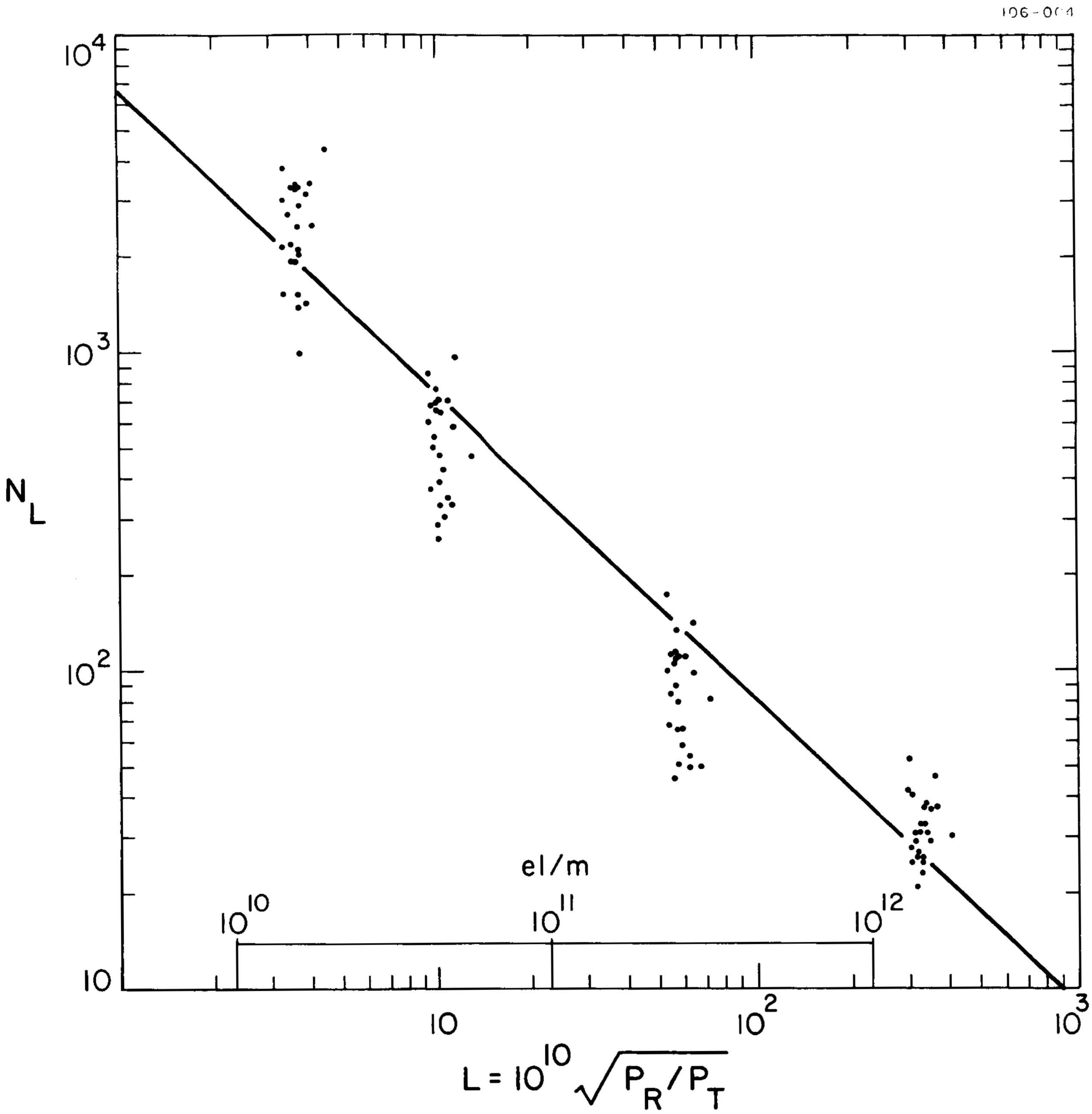

Figure 2. Counts N_L plotted against L. Straight line: s from linear fit; curved line: second-order polynomial fitted through the data.

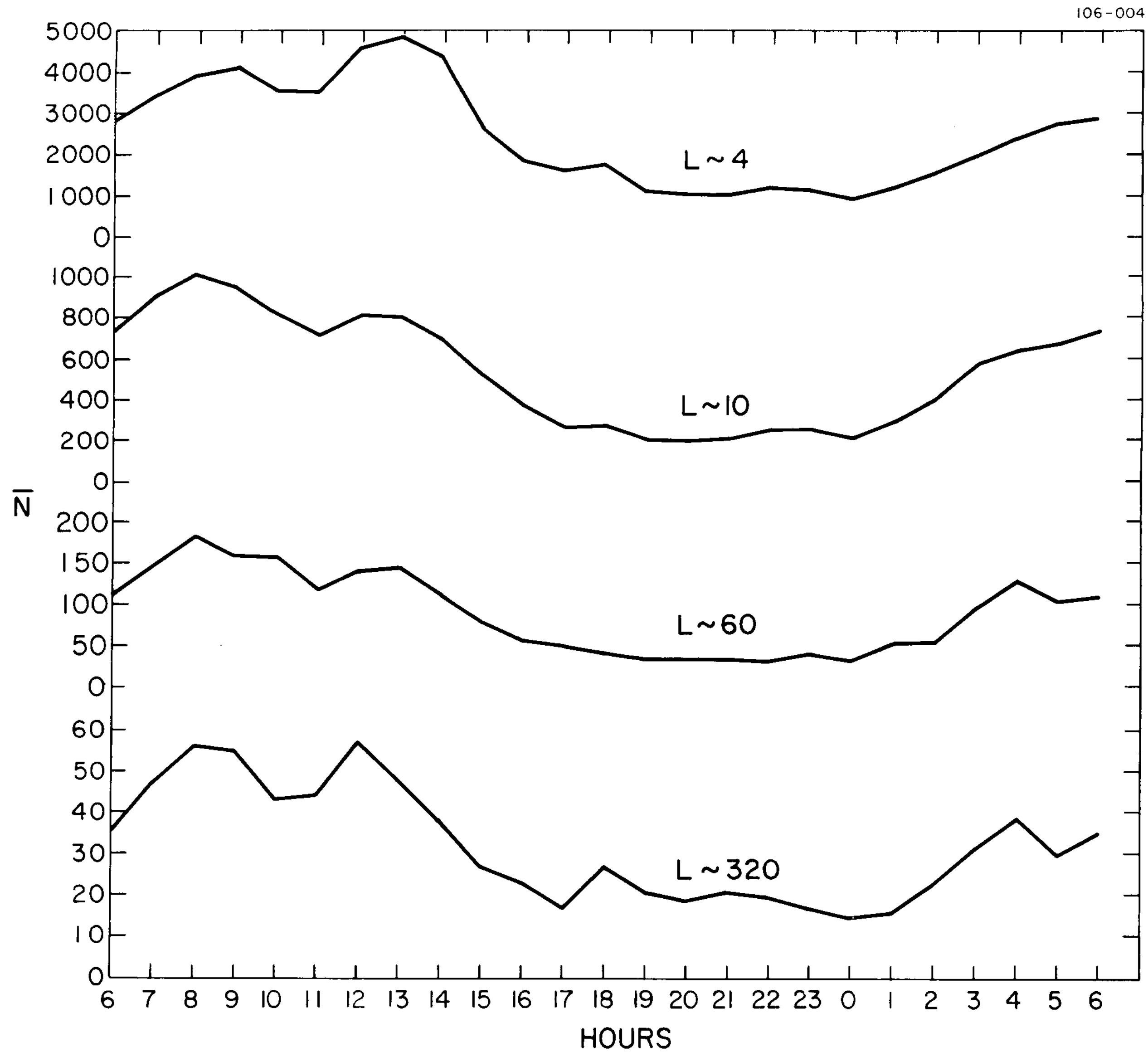

Figure 3. Diurnal variation in the echo rates from all the data.

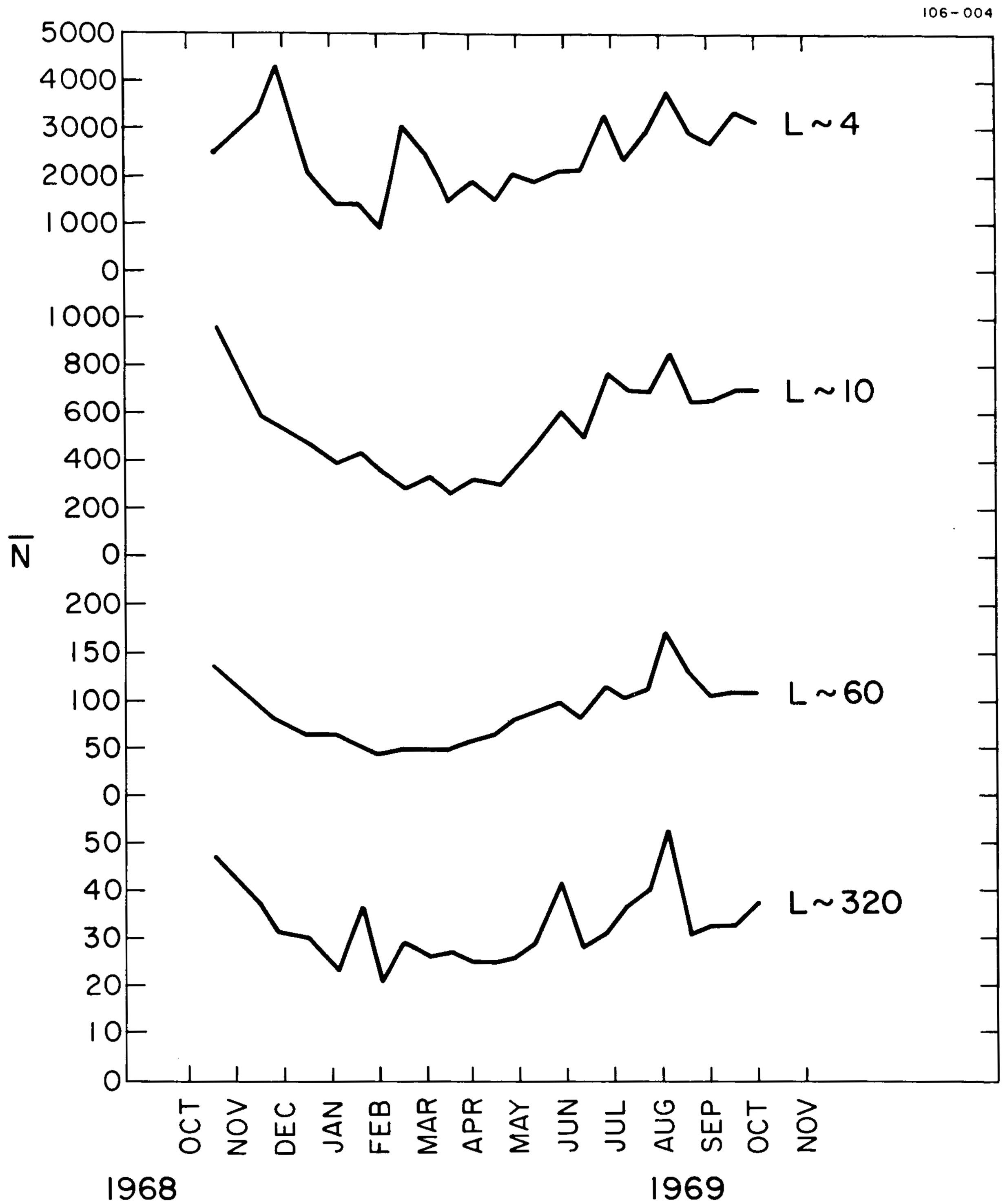

Figure 4. Mean rates as a function of time of the year.